DISTRIBUTED ACTIVE VIBRATION ABSORBER (DAVA) AND ASSOCIATED CONTROL APPROACHES FOR ACTIVE-PASSIVE REDUCTION OF SOUND AND VIBRATION

C.R. FULLER

Vibration and Acoustics Laboratories
Department of Mechanical Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0238

Presentation at DARPA TIM, Baltimore, MD June 2000

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

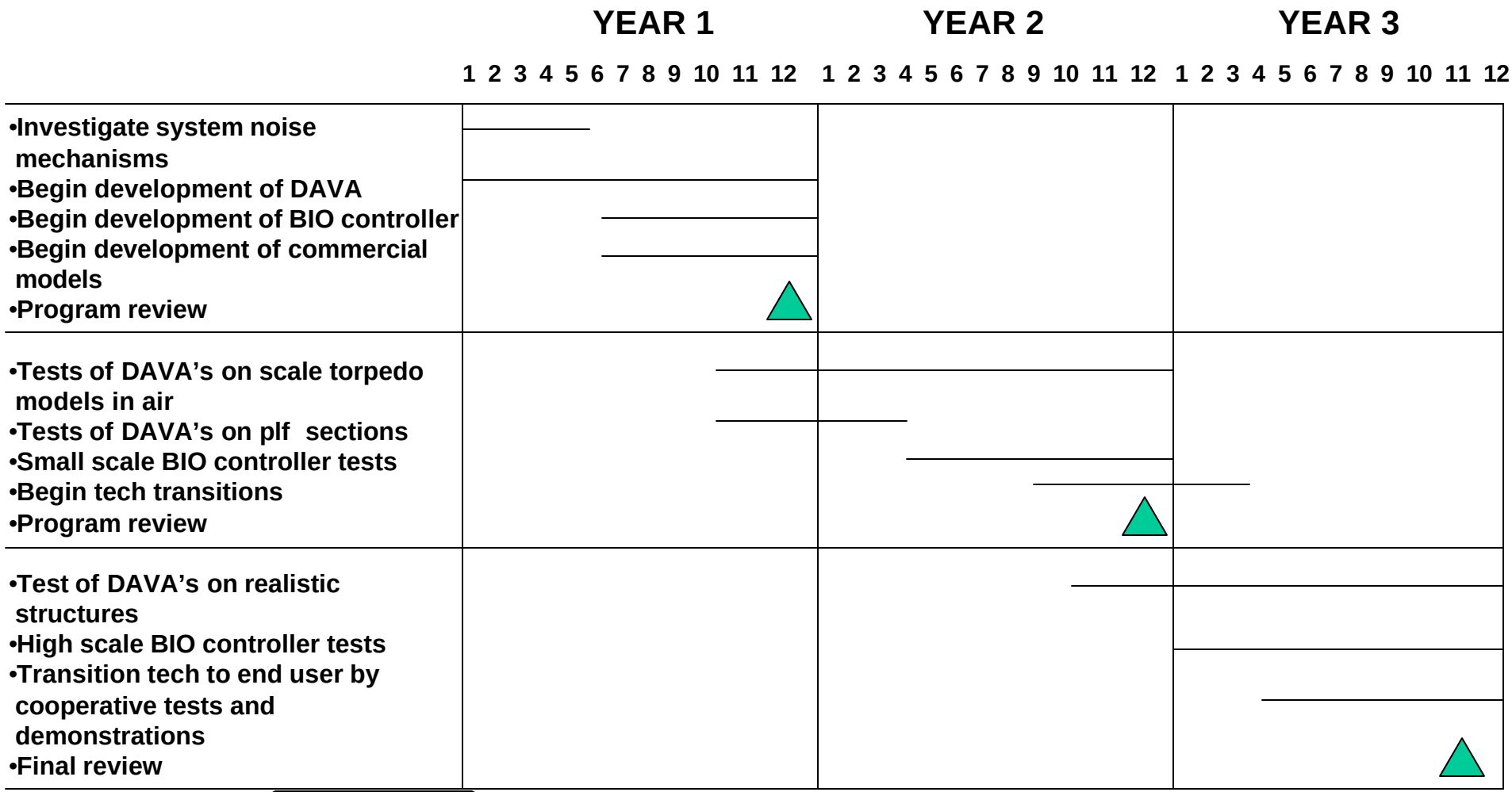
VAL

PROGRAM OBJECTIVES

- **To develop and demonstrate a prototype distributed active vibration absorber which is lightweight, conformal and cost effective.**
- **To develop and demonstrate a bio hierarchical controller approach for high actuator/sensor count system.**
- **To develop and demonstrate associated design procedures.**
- **To initiate transition of the technology to applications in AF launch vehicle payloads, USN Next Generation Torpedoes and NASA Aircraft Interior Noise Programs.**

Virginia Tech VAL
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

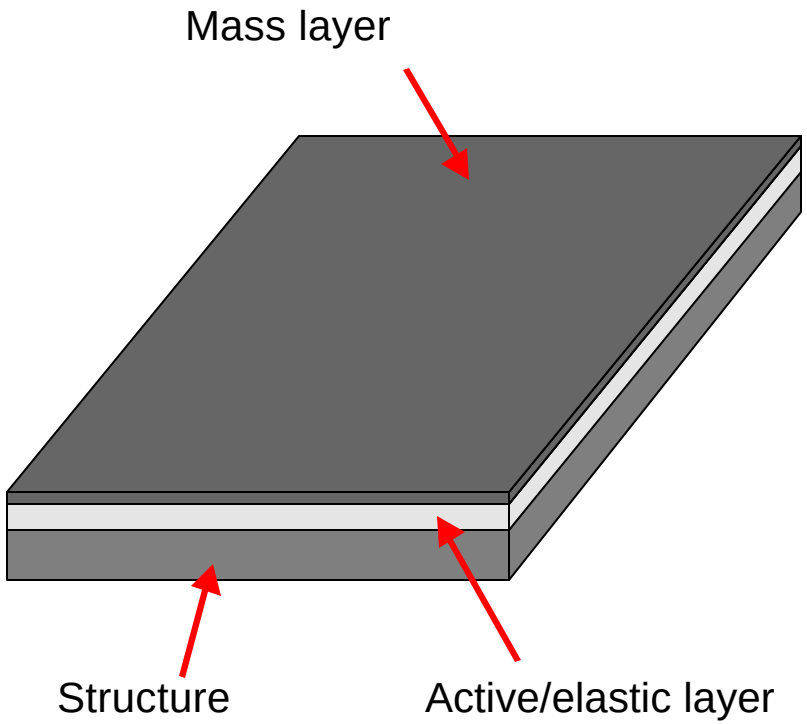
PROJECT TIMETABLE



Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

VAL

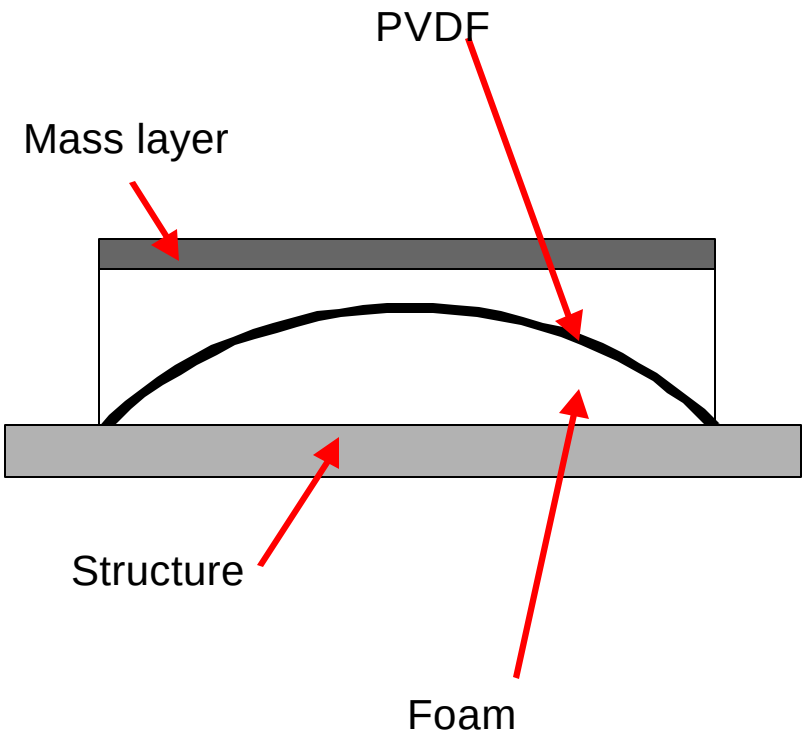
CONCEPT OF THE DISTRIBUTED ACTIVE VIBRATION ABSORBER



- **Mass spring layer applies a distributed reactive force to the structure.**
- **Achieves global reduction instead of minimizing at a single point.**
- **Squeeze film damping action at high frequency.**
- **Form a lightweight and conformal layer so it is easy to integrate into the structure.**
- **Active layer allows forces to be applied to the structure outside the bandwidth of the passive distributed absorber.**

Virginia Tech VAL

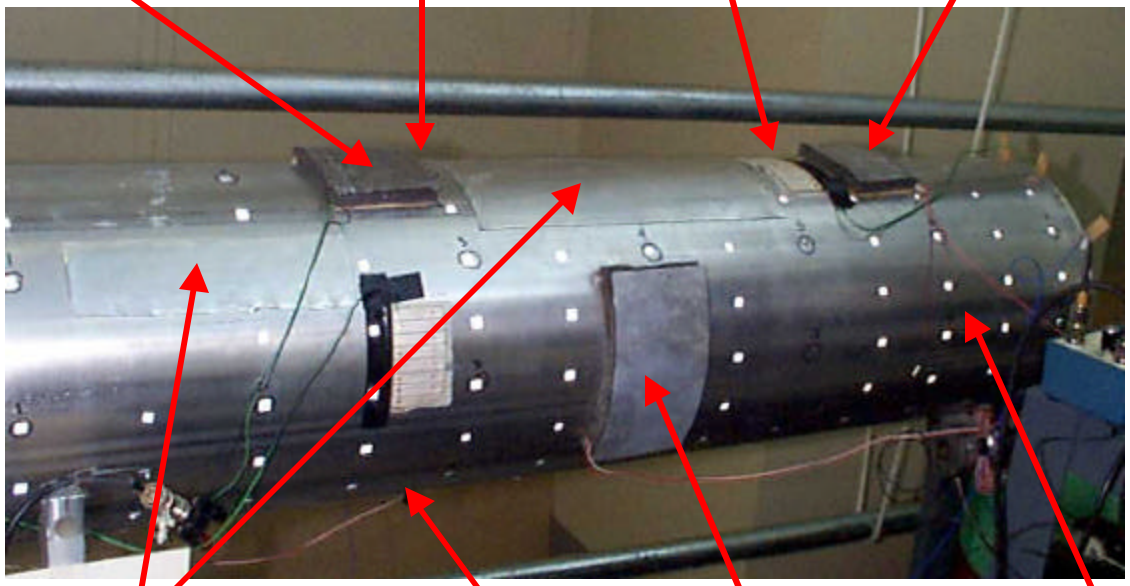
DISTRIBUTED ACTIVE VIBRATION ABSORBER USED FOR EXPERIMENTAL WORK



- Foam/PVDF acts as an elastic/active layer.
- Lead layer acts as a mass layer.
- DAVA is approximately 10 % of the structure weight.
- DAVA is only 1.3 cm thick.

Virginia Tech
VAL

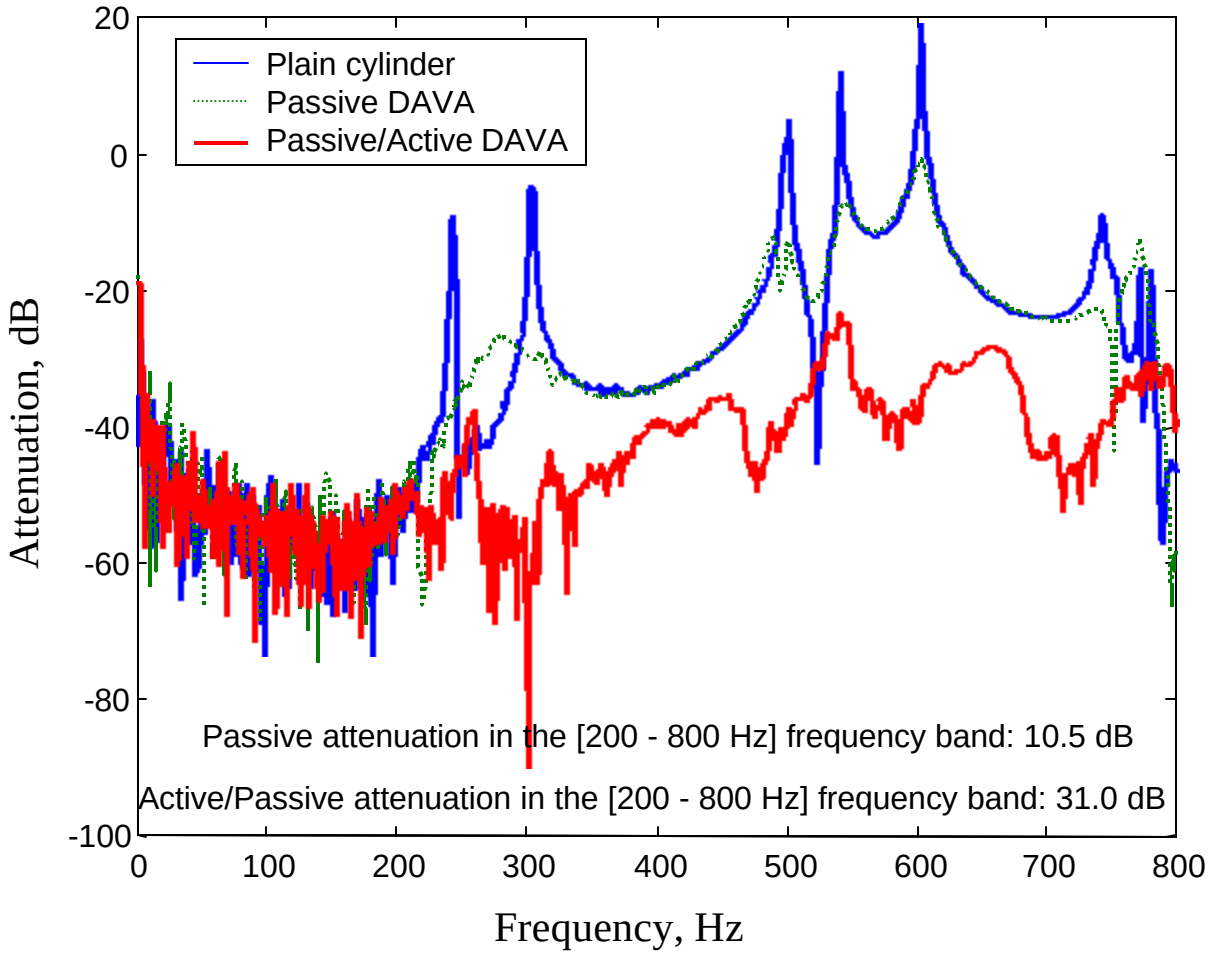
FEED-FORWARD CONTROL OF CYLINDER VIBRATION USING THE DISTRIBUTED ACTIVE VIBRATION ABSORBER



- **DAVA 1 and 2 are connected together so they act as only one actuator.**
- **Feed-Forward DIDO: 2 error sensors (accelerometers) and 2 actuators (DAVA 1-2 and DAVA 3).**
- **Broadband [0 - 800 Hz] disturbance provided by PZT.**
- **Test performed with and without viscoelastic patches.**

Virginia Tech VAL

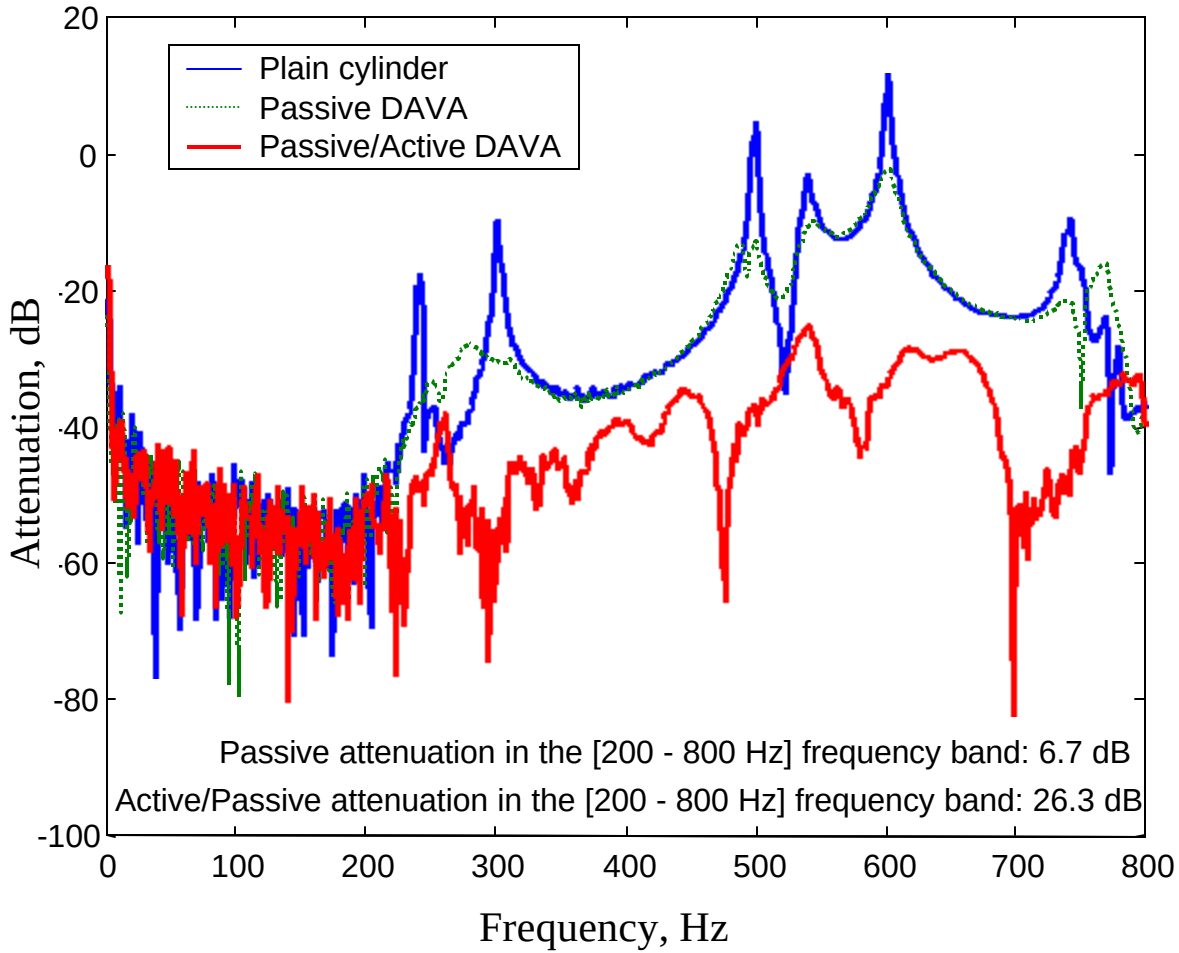
EXPERIMENTAL RESULTS WITHOUT VISCOELASTIC TREATMENT ON CYLINDER



Virginia Tech

VAL

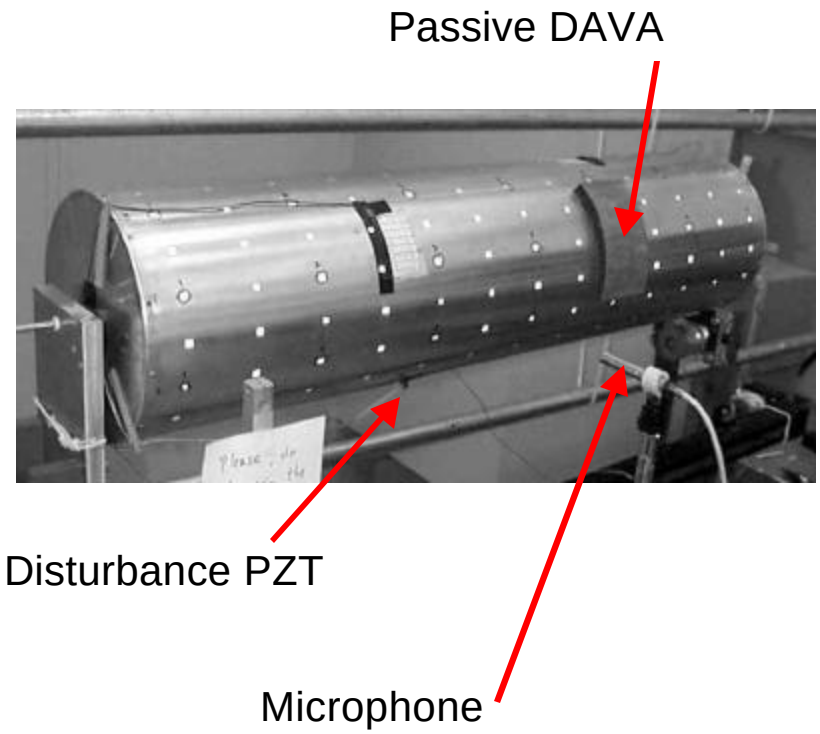
EXPERIMENTAL RESULTS WITH VISCOELASTIC TREATMENT ON CYLINDER

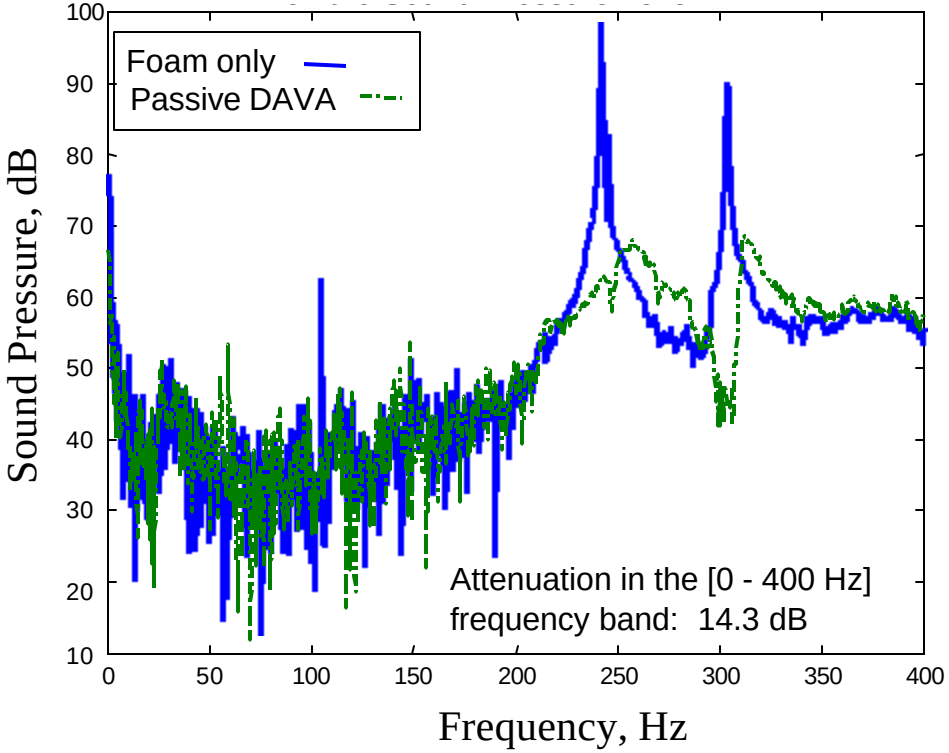


Virginia Tech

VAL

EFFECT OF THE DAVA MASS LAYER





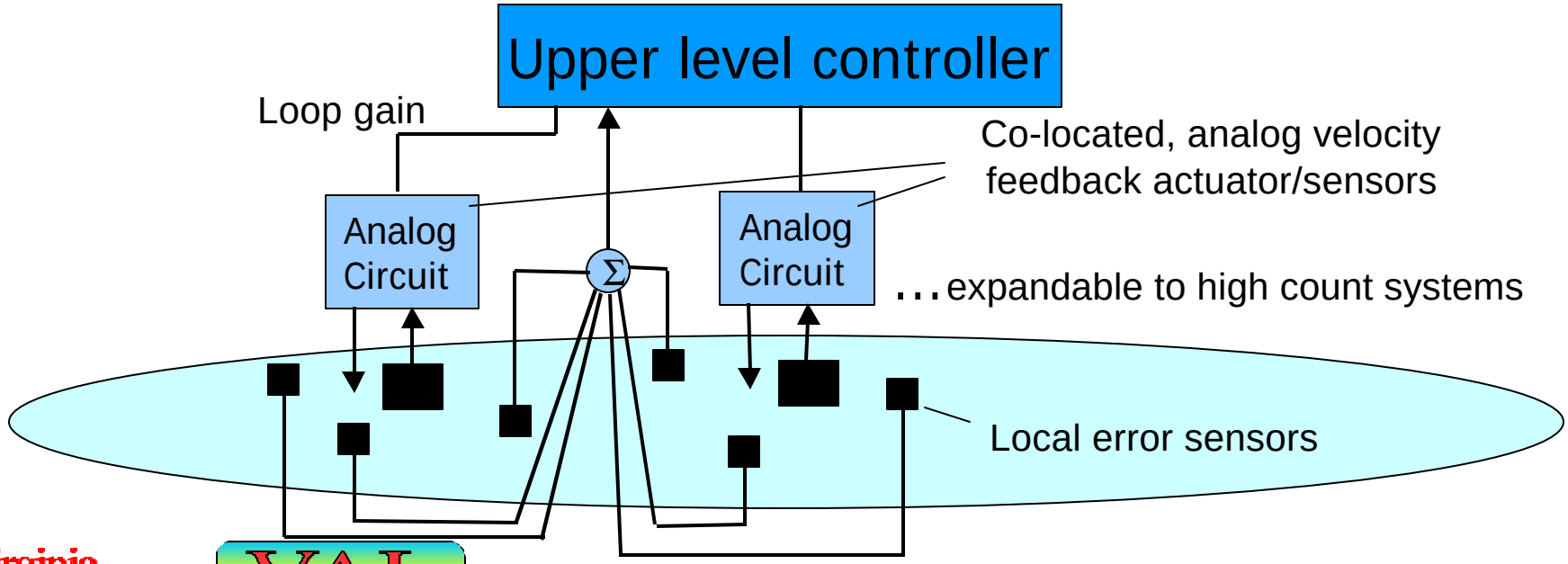
The DAVA passively acts as a distributed vibration absorber.

Virginia Tech VAL

CONTROL OF LARGE STRUCTURES USING HIERCHICAL ARCHITECTURES

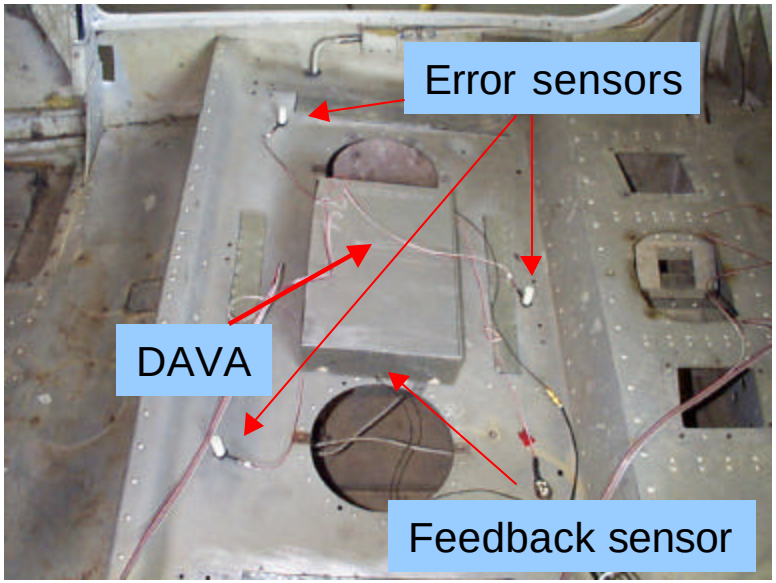
Concept

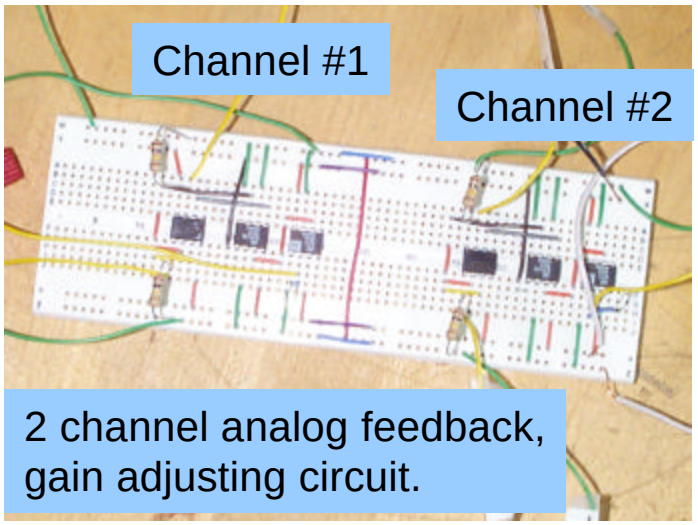
- **Many, simple, analog, independent local controllers**
- **Heuristic higher level digital controller**
- **User-friendly, cost effective, active control**
- **Stable sub units so easily expandable to high count systems**



Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
VAL

EXPERIMENTAL WORK





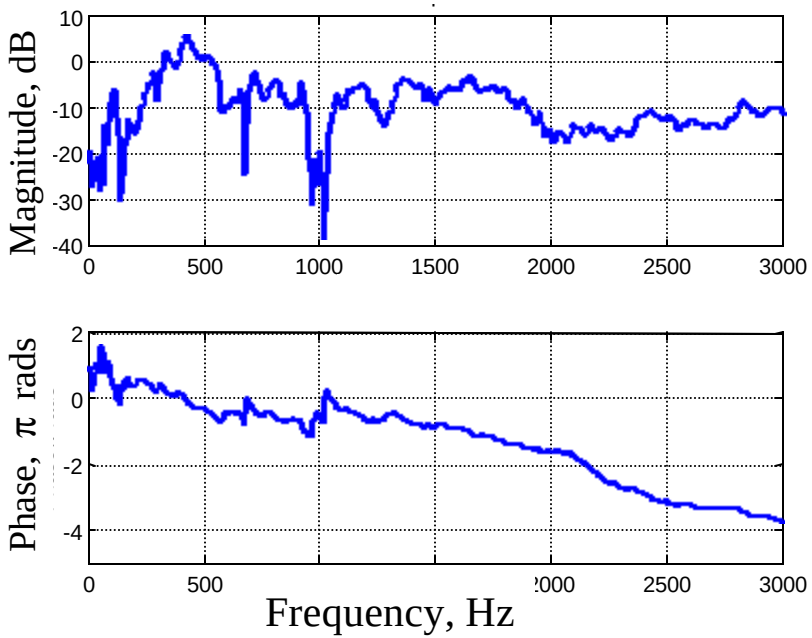
- **Remote broadband structural disturbance.**
- **2 DAVA's on complex structure.**
- **Construct minimum phase loop by combination of acc signals.**
- **Minimize sum of six error acc distributed between both panels.**
- **Simple analog circuit used to adjust the loop gain.**

Virginia Tech VAL

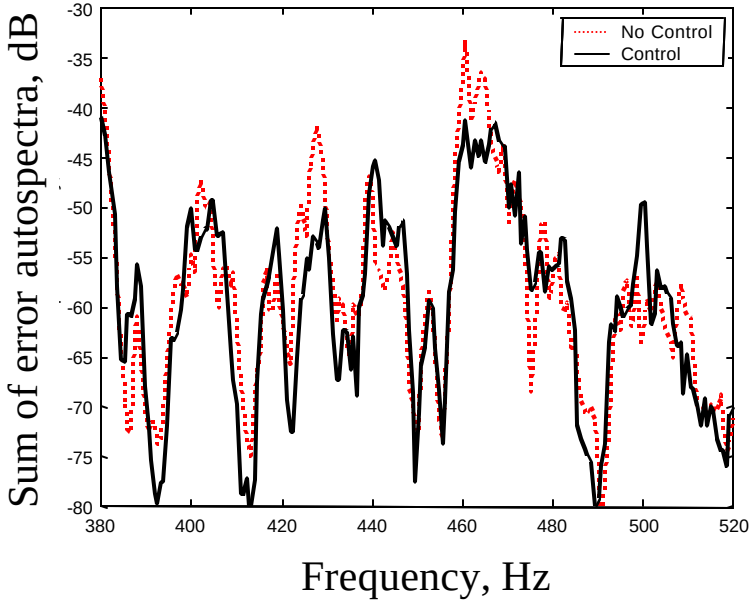
EXPERIMENTAL RESULTS

- **Co-located velocity feedback**
- **Analog feedback loop**
- **Minimum phase:- stable**
- **Natural roll-off due to actuator dynamics.**
- **Spatially distributed sensors as filters**
- **Minimum phase over large bandwidths.**

Feedback loop transfer function



380-520Hz



2dB reduction over bandwidth

12dB reduction at peak

Virginia Tech

VAL

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

DIRECTIONS FOR FURTHER RESEARCH ON THE HIERACHICAL CONTROLLER

- Expand to broad band control.
- Acoustic control.
- Advance and simplify hardware.
- Design actuator to behave as mechanical filter.
- Apply to complex structure.

PROGRAM MAJOR ACCOMPLISHMENTS IN YEAR 1

- Successfully developed and tested an effective DAVA
- Successfully applied the DAVA to a scale torpedo cylinder
- Successfully applied the DAVA to a launch vehicle PLF
- Uncovered and optimized DAVA mechanisms
- Developed theory for BIO controller
- Preliminary demonstrations of BIO controller

Virginia Tech VAL
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

CONCLUSION

- **DAVA's provide cost effective, compact control of vibration and sound over extended areas**
- **DAVA's are effective at very low frequencies**
- **BIO controller is a simple, cost effective replacement for present complex control approaches**
- **BIO controller has potential to extend to high actuator/sensor system**

TRANSITIONS

- **To AF for control of launch vehicle payload noise**
- **To USN for control of vibration and sound in the next generation torpedo**
- **To NASA for control of vibration and sound in aircraft and helicopters**

Virginia Tech VAL
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY